forest destroyed many more lives, also formed the subject of an official report from Lapham's pen. He visited the observer at Chicago the day after the fire, and finding that his reduction tables had burned, supplied new ones from his own copy. The termination of this arrangement came in the following form:

WASHINGTON, D. C., *May 11, 1872.*

Dr. I. A. LAPHAM,
Milwaukee, Wisconsin.

DEAR SIR: I am directed to inform you of the limited amount of money at the disposal of this office for the current year and the consequent necessity for the reduction of its working expenses. The arrangement by which your valuable services have been secured as Assistant to the Chief Signal Officer will terminate at the close of the present month.

It is hoped that the office will be in sufficient funds by that date to liquidate your account in full.

Respectfully,

H. W. HOWGATE,
Captain, and acting Signal Officer.

Of Lapham's later career it will suffice to mention that as chief geologist (April 10, 1873, to February 16, 1875) he organized and energetically directed the Wisconsin Geological Survey. He was beginning an investigation of temperatures and other conditions in the inland lakes of Wisconsin, with reference to fish production, when he died of heart failure while in a boat on Lake Oconomowoc, September 14, 1875.

Beginning January, 1871, Myer organized at Washington a corps of forecasters consisting of two civilians, Cleveland Abbe and Thompson B. Maury, and one officer, Lieut. A. W. Greely, and made them responsible for forecasting for the entire country. Maury afterwards joined the staff of James Gordon Bennett's New York Herald, for which he wrote a daily column of weather information published on the editorial page under the unique title "Personal Intelligence." Greely led the tragic *Lady Franklin Bay* Arctic expedition of 1881–1883, one of the two expeditions for meteorological observations that Myer had undertaken as America's share in an international attack on the problems of Arctic meteorology. Greely succeeded to the place of Chief Signal Officer, March 3, 1887, and remained in command of the Signal Corps when the Weather Bureau was separated in 1891. Cleveland Abbe occupied throughout his life the position of dean of the scientific staff of the National Meteorological Service and is probably best known as editor of the MONTHLY WEATHER REVIEW, and of three volumes of papers on the mechanics of the earth's atmosphere published by the Smithsonian Institution.

LITERATURE CITED

1. LAPHAM, I. A. Notice of the Louisville and Shippingport canal and the geology of the vicinity. Am. J. Sci. & Arts. ser. 1, vol. 14. 1828, p. 65–69.
2. LAPHAM, I. A. Miscellaneous observations on the geology of Ohio. State Doc. of Ohio, 1837, p. 31.
3. STODDARD, P. W. Story of the first geological survey of Ohio. Ohio Arch. & Hist. Soc. Pub., v. 37, 1928, p. 107–135.
4. LAPHAM, I. A. Antiquities of Wisconsin. Smithsonian Inst. Contrib. to Knowledge, v. 7, 1855.
5. National Board of Trade. Proceedings of the second annual meeting, held in Richmond, Va., 1869. Boston, 1870.
6. National Board of Trade. Proceedings of the third annual meeting.
7. Insurance Monitor. Vol. 23, p. 330.
8. ABBE, C. The meteorological work of the United States Signal Service 1870–1891. Weater Bureau Bull. 11, pt. 2, pp. 232–285.
9. WEBER, G. A. The Weather Bureau, its history, activities, and organization. New York, 1922.
10. Congressional Doc., Ser. No. 1431, Doc. 10.
11. Cong. Globe, 41st Cong., 2d sess., p. 177.
12. Letter from H. E. Paine dated October 8, 1903, to Mr. Duane Mowry, Milwaukee, Wis., quoted by permission of Mr. Mowry.
13. Cong. Doc., Ser. No. 1416, Doc. 10, pt. 2.
14. H. R. Misc. Doc. No. 105, 41st Cong., 2d sess., vol. 3.
15. Estimates of Appropriations for the Army for 1870–71, 41st Cong., 2d sess., Ex Doc. No. 5.
16. Annual Report of the Chief Signal Officer. 1870, p. 11.
17. Annual Report of the Chief Signal Officer, 1871, Paper No. 1½, beginning p. 167.

ANTARCTIC METEOROLOGY

By HENRY T. HARRISON

[Weather Bureau, Cleveland, Ohio]

The title "Antarctic Meteorology" may seem misleading and rather presumptious. To even begin to cover so vast a subject in a limited paper is of course out of the question. However, it is the aim here to present (1) only the general features of prevailing conditions, as now known, existing over the continent as a whole, and (2) to describe in detail some of the results of a 15 months series of observations made in one locality.

It appears to be fairly well established now that Antarctica is in the waning stages of one of the severest ice ages ever known. Save for bare rocky outcrops and bare sharp peaks the entire continent lies buried beneath the accumulation of centuries of snow and ice ranging upward to an estimated depth of several thousand feet on the polar plateau itself. Surrounded on all sides by the comparative warmth of ocean water, the cold continental air is constantly being mixed with violently opposed air masses from over the seas. Acting as a huge refrigerator the continental ice cap not only produces a steep temperature gradient in winter but maintains it to a lesser degree even during the short summer season. Add to this turbulent influence the typical glacial action of producing local but violent "fall" winds and we have the basic reasons for the unusual atmospheric activity over most of Antarctica, the stormiest area in the world. Sir Douglas Mawson aptly named it "The Home of the Blizzard." At his winter base in Adelie Land south of Australia hurricane winds were of almost daily occurrence and occasional gusts neared a velocity of 200 miles per hour.[1] Captain Scott and Sir Ernest Shackelton experienced very nearly the same winds although interspersed with a far greater proportion of calms at McMurdo Sound near the western edge of the Ross Sea.[2] Little America and the Bay of Whales region are comparatively free from violent hurricane winds although just 100 miles to the east at the foot of the Rockefeller Mountains the geological party of the Byrd Expedition experienced one storm during which the wind reached an estimated velocity of 150 miles per hour. The oceans surrounding Antarctica are generally recognized as being the stormiest waters in the world. The extreme local nature of many of the storms has been proven time and again. After the aforementioned Rockefeller Mountain hurricane there were evidences that little more than a moderate gale had prevailed just a few miles away while, at Little America, the same storm produced a wind of only 50 miles per hour (22.4 m. p. s.). Mawson and his party in Adelie Land found the almost unbe-

[1] Mawson, Douglas. The Home of the Blizzard.
[2] Shackelton, Ernest Henry. Scott's Last Expedition. London.

lievable combination of a strong gale and a light breeze prevailing side by side within the limits of a few miles.[1]

At widely scattered intervals but especially during winter great cyclonic storms develop somewhere near the rim of the continent and are attended by severe blizzards over a wide area. Definite paths of these cyclones remain unknown although one well defined track appears to lie along or near the Antarctic Circle with general movement from west to east. Professor Hobbs holds to the theory that a great glacial anticyclone covers the interior of the continent and this view is shared by others although as yet no definite conclusions may safely be drawn because of the scarcity of available data. Only scattered and irregular observations have been made on the polar plateau during two of the summer months and winter conditions there are absolutely unknown. Another theoretical distribution of pressure places an anticyclone over the polar plateau and, surrounding it, a series of cyclone centers which move in unbroken succession from west to east along the outer edge of the continent. The normal drain of air is from the pole outward toward the sea at the surface but, due to deflection by the earth's rotation, winds become easterly or southeasterly near the oceans. Theoretically this outpouring of air at the surface would be offset by an inflow at higher levels of air from lower latitudes. Pilot-balloon soundings bear out this theory for the most part although many instances have occurred where winds were from the south up to altitudes of 4 miles (5,000 meters) and occasionally even into the stratosphere.

Due to excessive cooling near the ice surfaces sharp inversions of temperature prevail at low levels aloft during periods of calms or light winds; hence the blizzard winds, which actually blow from the colder interior, are almost invariably attended by rapidly rising temperatures at the surface as a result of the mixing of the two layers of air. Evidences also show that many of the blizzards, expecially those in the Ross Sea region, are simply relief valves by means of which enormous masses of cold air which pile up in the interior are dumped over the sea, somewhat in the manner of the working of a hydraulic ram. During the expeditions of Scott, Shackelton, and Byrd it was noted that any protracted period of extreme cold on the Ross Barrier, or Ice Shelf as it is now known, was invariably followed by a severe blizzard at the edge of the Ross Sea. Once an initial release was given to this sluggish mass of dammed up air—and this could be accounted for by a weakening of pressure in the Ross Sea—a violent outpouring would result for a day or two until equilibrium was once again established. Simpson [2] points out that a semipermanent area of relatively low pressure prevails over the Ross Sea as a result of the steep temperature gradient maintained in that region and that even a slight strengthening of the pressure gradient would be sufficient to supply the initial energy for the release of a blizzard.

Little America was the base camp of the Byrd Antarctic expedition from December, 1928, until February, 1930, and was established on slightly rolling slopes of the Ross Barrier at the Bay of Whales in the southeastern corner of the Ross Sea. The ice shelf in this region is floating in salt water with the nearest visible land and also the nearest known land lying 100 miles to the eastward. Pilot-balloon soundings and detailed surface observations were made daily over this 14-month period while soundings of the upper air by means of kites were made during the final season.

A smooth recording of data was beset with many difficulties, most of which could be traced to the weather itself, wind and cold. Because of their relative importance the pilot-balloon soundings were begun back in the early stages of the camp during the bustling days of unloading, sledging and snow-shoveling. At that time everyone was working from 12 to 15 hours each day in an effort to get the camp firmly established before winter set in, yet sufficient spare time was found each day to make at least one observation of the upper air currents. The balloons were inflated inside a tent and the readings made with a theodolite placed on the surface of the barrier, exposed to wind and cold. A succession of blizzards in February and March kept the instrument snowed under constantly so that it was necessary to shovel it out before each observation. Toward the end of April, however, attention was given to the building of a permanent shelter and stand adjoining the vestibule of the administration building with a telephone connection with the scientific room inside the house, thus doing away with the necessity of recording data outside in the cold. Because of the danger from fire inside the house the balloons were inflated with hydrogen in the tunnel exit of the house where the temperature averaged 40° below zero and this fact alone was the cause of more than one ruffled disposition. As the dark winter came on and the temperature dropped still further the lens and eye-piece of the theodolite were subjected to thick accumulations of rime frost until it became necessary to scrape off these coatings with a small stick every minute or so during observations in order to avoid losing sight of the balloon. Occasionally frost formed on the inside of the lens and whenever this happened the instrument had to be taken inside the house and thoroughly "baked out" over the stove. The small paper lanterns used in the night work were another source of worry. Unless well heated beforehand the tallow candles would refuse to burn properly in the cold and frequently went out entirely after the balloon was released. On one occasion five balloons were released before one continued to burn properly; consequently there was more than one reason for rejoicing when the sun returned to Little America in August and the lanterns and lights could be discarded. After a suitable combination of headgear, footgear and gloves had been worked out by experiment little discomfort was experienced in observing the balloons during the coldest weather of mid-winter when the temperature sometimes fell as low as −70° F. (−57° C.) Four hundred and fifteen soundings were made during the 14 months to an average altitude of almost 3 miles (4,500 meters). Curiously enough these observations furnished practically the only basis for making predictions of coming conditions for flight and camp activities. Generally speaking a deep southerly current aloft attended or preceded settled clear conditions and good visibility whereas northerly winds aloft were nearly always associated with thick overcast skies and low visibility. Attempts to interpolate general pressure distribution from local wind and barometric changes were so disappointing that nearly all forecasts were made on the basis of the prevailing upper winds and the assumption of their importation as air masses of varying degrees of temperature and moisture.

The kite work received an early setback when a large crate of parts was lost during one of the blizzards which swept over the camp in March. Replacement was impossible at that time and so it was late in the winter before enough spare parts could be made up to permit assemblage of the kites. For this purpose construction was begun on a large house of snow blocks with one end partitioned

[1] Mawson, Douglas. The Home of the Blizzard.
[2] Shackelton, Ernest Henry. Scott's Last Expedition. London.

off into a work room and the remainder serving as storage space. Interrupted by a 50-mile blizzard which blew down three of the main walls in a mass of ruin, the work was finally completed, the house roofed over with canvas supported by bamboos and a small blubber stove constructed for heating the work room. On a cold day outside the stove would raise the temperature inside the house to about 0° F. (−17.8° C.), just enough to allow bare handed work on the joints and wrappings of the kites. It was in this manner that these structures, of the Marvin-Hargraves cellular type, were set up and made ready for service. The first flight was begun on a particularly cold and disagreeable day in September when working conditions outside were anything but pleasant. After four men had been frostbitten about the hands and face before the flight was finished there was nothing to do but postpone further action until the arrival of more moderate weather. Flights were made with fair regularity during the next three months but were limited in altitude due to failure of the motor driven reel and the necessity of resorting to hand reeling. The prevalence of low stratus clouds during a majority of the flights resulted in quite heavy deposits of hard rime upon the kites and wire, great enough on several occasions to force the kites down, to the surface. These deposits, while not strictly ice were layers of very closely packed frost crystals which built up on all windward surfaces of kites and wire sometimes to a thickness of 3 inches (7.7 centimeters) during the course of several hours exposure in the subcooled clouds. The fact that rime formed on every occasion when kites entered clouds is significant in that it points out a very evident danger which attends the use of dirigibles in polar latitudes. Aeroplane flights at Little America were made only when the sky was clear and so no opportunities were offered for the study of ice formation on heavier-than-air craft.

Fog, while infrequent, was important from the point of view of demonstrating that water vapor can exist in a subcooled state in nature at temperatures far below the freezing point. On one occasion fog formed at −30° F. (34.4° C.) which was dense enough to obscure objects at a distance of 1,000 feet (300 meters). Lighter fogs were observed at −40° F. (−40° C.) but below this point the water vapor ordinarily gave away to a haze of floating ice crystals. Subcooled fog was also attended by a formation of rime. On June 11 a combination of fog and misting rain at a temperature of 5° F. (−15° C.) resulted in the formation of a fringe of rime as much as 4 inches (10.2 centimeters) in thickness on the windward surfaces of all exposed objects. The mist was first attended by a thin coating of glaze before rime began to form. This fall of rain in the dead of winter implies that an enormous temperature inversion existed somewhere above the base of the stratus clouds, a fact which can be explained by the prevalance of northerly winds aloft at the time. These winds were warmed by passage over the open water of the Ross Sea and possibly originated as far north as the Pacific Ocean. Precipitation in the form of snow was almost impossible to measure due to the heavy drift which accompanied most falls. Careful estimates, however, placed the annual snowfall at 103 inches (262 centimeters) which is in fair agreement with figures reported in the McMurdo Sound section. Sleet was unknown at Little America.

Cloudiness and relative humidity averaged high whenever the Ross Sea was open which is to say during most of the year. The two forms of overcast sky, peculiar to polar regions, "ice blink" and "water sky," were of frequent occurrence. The former is the milky, suffused glow upon clouds over snow and ice and the latter the pronounced dark reflection upon clouds over water. Standing on the barrier and looking to the north the sky presented a dark threatening appearance while overhead the sheet of stratus cloud was simply a milky gray blur devoid of all form. On days of this type the outlook was gloomy and discouraging indeed. No horizon was visible except to the north, a murky haze filled the air and, in the lack of contrasting shadows, it was impossible to distinguish any form in the snow at one's feet. Walking about on the rough snow one not only had difficulty maintaining a balance on the uneven surface but the strain on the eyes was often greater than that during the glare of bright sunlight. Ordinarily the line between the water sky and the ice blink was so marked that the edge of the barrier was perfectly outlined on the cloud layer above. Whenever scattered ice floes invaded areas of open water a mottled reflection upon the clouds resulted. In marked contrast to these dull depressing days the sky was often beautifully clear and presented a wide range of colors and delicate tints when the sum was low. Brilliant solar and lunar halos, parhelia, coronæ, the aurora and weird mirage effects—all of these played their part in breaking up the monotony of an everlasting white landscape.

The thermograph and hygrograph, self-recording instruments in the shelter outside, furnished a disagreeable duty once each week when the record sheets were changed. Both instruments were carried inside a tunnel where the temperature was nearly that of the outside air but with the advantage of being protected from the wind. Silk gloves worn during this operation furnished little protection for the hands at −50° F. (−45° C.) but prevented an actual contact with the cold metal of the clocks which would freeze bare finger tips instantly. The clocks themselves behaved beautifully in the cold weather after all trace of oil had been removed from the works with ether. The thermograph did stop when the temperature first touched −70° F. (−57° C.) but after a few minor adjustments were made no more trouble was had with either clock. The fine powdery drift of the blizzard was extremely troublesome through its action of sifting through minute cracks and blocking all movement of the pens. It also built up around the cogwheels with enough pressure to force the clocks off their bases at times. Almost constant attention had to be given to the instruments during the more severe blizzards. The anemometer also suffered in the cold due to an unequal contraction of the brass and steel parts and to the hard gritty layers of rime which formed on the cups. In spite of all of these little handicaps the instruments functioned as well as could be expected under the severe conditions and the records on the whole were consistent and trustworthy.

The severity of the Antarctic cold needs little discussion here. Any climate which can and does produce subzero temperatures (F.) every month in the year is truly frigid and when it combines strong winds with the cold as it often does life in the open is unpleasant indeed. The winter temperatures at Little America were not as severe as those sometimes recorded in the interior of Northern Siberia but the average temperature for the calendar year of −12.7° F. (−24.8° C.) was the lowest ever recorded over a similar period anywhere.[3] The lowest figure during the year was −72.4° F. (−57.8° C.) but a far more severe condition than this prevailed in July when a combination of a 25-mile (11.2 m. p. s.) wind and a temperature of −64° F. (−53.3° C.) was

[3] According to G. C. Simpson (*see* British Antarctic Expedition, 1910-1913, Vol. 1, Calcutta, 1919, page 91, Table 52) Framheim had a mean temperature for one year of −14.4 F., two months being interpolated.—EDITOR.

experienced. Kerosene lanterns froze up at $-55°$ F. ($-48°$ C.) and dry-cell flashlights were rendered useless also. Self-generating dynamo flashlights furnished the only source of light for outside use during the severe cold weather.

In conclusion it may be well to emphasize the fact that there is still an enormous field for meteorological research in Antarctica. Professor Hobbs has long pointed out the great value which would accrue from a year's observations on the polar plateau; such work would be possible although attended with extreme difficulties and hardships to the personnel involved. Simultaneous records at a number of points over the continent are also needed before a really comprehensive and intelligent study may be made of the laws which govern atmospheric action in the southern latitudes. Each expedition has added a bit more to this knowledge yet the field of operations of one or two isolated parties has necessarily been limited. The extent and rapidity of future research hinges, as heretofore, upon the generosity of the people and of organizations in offering financial support for expeditions.

REPORT OF THE STREAM-FLOW PREDICTION SUBCOMMITTEE[1]

By A. STREIFF, Consulting Engineer

[Jackson, Mich.]

The past year was characterized by a greatly increased universal interest in the possibilities of estimating stream flow, which previously has been and, in many professional and scientific quarters, still is regarded as being wholly a fortuitous sequence. During the past decade this viewpoint had gradually undergone a radical change, until to-day many earnest investigators recognize the presence of definite systematic elements in stream flow which permit conclusions to be drawn as to future run-off well in advance of occurrence.

PAST METHODS OF PREDICTION

In the planning of hydraulic projects, the manner of estimating future discharge quantities in the past has rested on a rather questionable basis, untenable on scientific grounds, and dictated by necessity rather than secure, basic knowledge. If stream flow is to be regarded as wholly fortuitous sequence, then the theory of probability is directly applicable to the estimate of future performance. Much has been theorized on future probability (probability a priori) based on past performance or experience (probability a posteriori) or so-called empirical determination of probability. It is a well-established fact that only a voluminous series of data can furnish a secure basis for future expectation. Such data must, moreover, be wholly freed from systematic sequences.

Instead of thousands of observations, hydraulic engineers usually have at their disposal only a few records covering not more than 10 to 50 years. It is evident that 50 dice throws will not give the same average as several thousand, and if systematic changes are introduced, such as changing the throw, the dice, etc., no reliable estimate of future averages based on previous performance is possible. Yet, this is the meager basis on which all hydraulic projects hitherto have been based. The future is held to have the same average, as well as limits of variation, as the past records indicate.

NEW METHODS OF PREDICTION

Certain it is, that stream flow records never repeat themselves, and ceaseless fluctuations exist, continually moving to higher and lower levels apparently in often recognizable systematic sequences. In Europe these have been studied and applied by Dr. Axel Wallen (Twelve Years of Long Distance Prognostication of Rainfall and Waterlevels, Annals der Hydr. und Maritim. Meteorology, September 1926, pp. 89–92), director of the hydrographic service in Sweden. Here, too, much research has been applied to finding a better way of estimating future stream flow. It is the near future which is of the greatest importance in hydraulic power projects, and this may be radically different from the immediate past; enough to create the difference between earned or not earned interest on outstanding bonds.

UTILITY OF PREDICTIONS

Experience of the past 10 years indicates that public utilities which derive their power supply in whole or in part from hydroelectric plants can apply these studies profitably to the appraisal of their future power supply. It appears that for the Great Lakes division it is quite possible to estimate hydraulic power output a year in advance to within 5 per cent. The general trend can be forecast for several years to follow, and thereby the steam power and coal supply requirements can be budgeted more accurately. No errors need be made as by one utility, which constructed an expensive booster pump installation for their circulating water just in advance of the rise in levels of the Great Lakes, or by another in the Great Lakes region, which hurriedly installed expensive additional boiler capacity to take care of threatening shortage just in advance of a rising hydraulic power output.

STREAM FLOW IN GREAT LAKES REGION

The Great Lakes region appears to be distinguished by a singularly regular multiannual sequence of stream flow, which enables close estimates of water power. Naturally such estimates are of greater value, the greater the amount of available storage. Without storage the annual (seasonal) variation determines the requirements of steam power; peak capacity is not affected by a variation of the annual mean, although even in such cases the annual coal supply is still subject to calculation in advance. Members of the Great Lakes division are enabled to utilize the knowledge of these systematic sequences of stream flow in the Great Lakes region to the extent above indicated.

The discovery of this regular cycle in stream flow is due to the hydrologist, Robert E. Horton (United States

[1] Extracted from the 1929-30 Report Hydraulic Power Committee, Engineering Section, National Electric Light Association, Great Lakes division. Presented at the tenth annual convention, French Lick, Ind., Sept. 25-27, 1930.